Chapter 2. Oceanographic Conditions

INTRODUCTION

The City of San Diego regularly monitors oceanographic conditions of the water column to assess possible impacts from the outfall discharge as well as the affects of the local oceanographic conditions on the fate of the discharge. Water quality in the South Bay region is naturally variable, but is also subject to various anthropogenic sources of contamination such as discharge from the South Bay Ocean Outfall (SBOO) and non-point source discharges such as San Diego Bay and the Tijuana River. These 2 non-point source discharges include 415 and 1731 square miles of watershed, respectively, and contribute significantly to nearshore turbidity, sedimentation, and bacteriological densities (Largier et al. 2004). The SBOO discharges treated wastewater approximately 5.6 km off shore at a depth of about 27 m, with an average daily flow rate of 24 mgd in 2005.

The fate of SBOO wastewater discharged into offshore waters is determined by oceanographic conditions and other events that suppress or facilitate horizontal and vertical mixing. Consequently, measurements of physical and chemical parameters such as water temperature, salinity and density are important components of ocean monitoring programs because these properties determine water column mixing potential (Bowden 1975). Analysis of the spatial and temporal variability of these 3 parameters as well as transmissivity, dissolved oxygen, pH, and chlorophyll can elucidate patterns of water mass movement. Taken together, analyses of such measurements for the receiving waters surrounding the SBOO can help (1) describe deviations from expected patterns, (2) reveal the impact of the wastewater plume relative to other inputs such as San Diego Bay and the Tijuana River, (3) determine the extent to which water mass movement or mixing affects the dispersion/dilution potential for discharged materials, and (4) demonstrate the influence of natural events such as storms or El Niño/La Niña oscillations. The combination of these measurements of physical parameters with assessments of bacteriological concentrations (see Chapter 3) provides further insight into the transport potential surrounding the SBOO throughout the year.

This chapter describes the oceanographic conditions that occurred during 2005 and is referenced in subsequent chapters to explain patterns of bacteriological occurrence (see Chapter 3) or other effects of the SBOO discharge on the marine environment (see Chapters 4–7).

MATERIALS AND METHODS

Field Sampling

Oceanographic measurements were collected at 40 fixed sampling sites located from 3.4 km to 14.6 km offshore (**Figure 2.1**). These stations form a grid encompassing an area of approximately 450 km^2 and were generally situated along 9, 19, 28, 38, and 55-m depth contours. Three of these

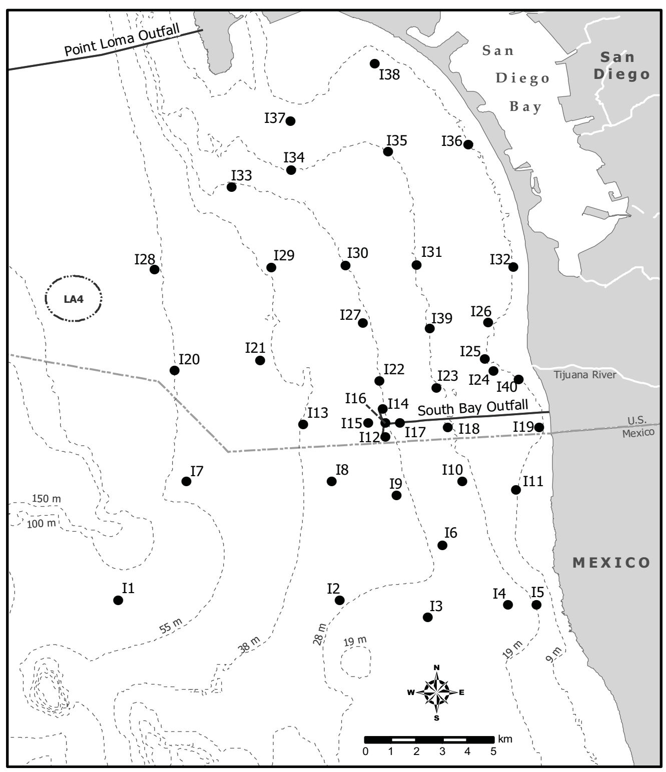

Figure 2.1
Water quality monitoring stations where CTD casts are taken, South Bay Ocean Outfall Monitoring Program.

stations (I25, I26, and I39) are considered kelp bed stations subject to California Ocean Plan (COP) water contact standards. These 3 stations were selected for their proximity to suitable substrates for the Imperial Beach kelp bed; however, this kelp bed has been historically transient and inconsistent in terms of size and density (North 1991, North et al. 1993). Thus, these stations are located in an area where kelp is only occasionally found.

Oceanographic measurements were collected at least once per month over a 3–5 day period. However, offshore monthly water quality sampling was not conducted in February 2005 pursuant to a resource exchange agreement between the City of San Diego and the Regional Water Quality Control Board (City of San Diego 2005b). Data for temperature, salinity, density, pH, transmissivity (water clarity), chlorophyll *a*, and dissolved oxygen were recorded by lowering a SeaBird conductivity, temperature and depth (CTD) instrument through the water column. Profiles of each parameter were constructed for each station by batch process averaging of the data values recorded over 1-m depth intervals. This ensured that physical measurements used in subsequent data analyses corresponded with bacterial sampling depths. Further details regarding CTD data processing are provided in the EMTS Division Laboratory Quality Assurance Plan (City of San Diego in prep.). To meet the COP sampling frequency requirements for kelp bed areas, CTD casts were conducted at the kelp stations an additional 4 times each month. Visual observations of weather and water conditions were recorded prior to each CTD sampling event.

Monitoring of the SBOO area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging (OI) of Solana Beach, CA. All usable images captured during 2005 by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite were downloaded, and several quality Landsat Thematic Mapper (TM) images were purchased monthly. Aerial images were collected with OI's DMSC-MKII digital multispectral sensor (DMSC). Its 4 channels were configured to a specific wavelength (color) combination which, according to OI's previous research, maximizes the detection of the SBOO plume's turbidity signature by differentiating between the wastewater plume and coastal turbidity. The depth penetration of the sensor varies between 8 and 15 m, depending on overall water clarity. The spatial resolution of the data is dependent upon aircraft altitude, but is typically maintained at 2 m. Several aerial overflights were performed each month for a total of 11 flights from January through April and November through December and 6 flights from May through October.

RESULTS AND DISCUSSION

Expected Seasonal Patterns of Physical and Chemical Parameters

Southern California weather can be classified into 2 basic "seasons", wet (winter) and dry (spring through fall) (NOAA/NWS 2005), and certain patterns in oceanographic conditions track these "seasons." In the winter, water temperatures are cold and the water column is well-mixed resulting in similar properties throughout the water column. In contrast, dry summer weather warms the surface waters and introduces thermally-sustained stratification that is occasionally interrupted by upwelling events. Despite a sampling schedule that is spread out over several days during each month, historical analyses of oceanographic data collected from the South Bay region support this pattern (**Figure 2.2**).

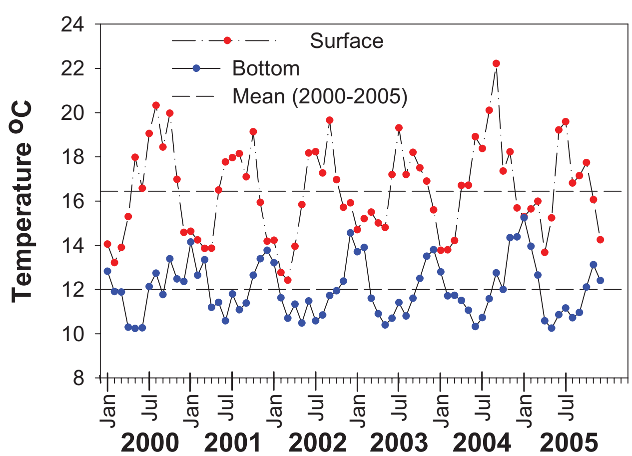

Figure 2.2
Average monthly surface and bottom temperatures (°C) for 2000–2005 compared to overall mean temperatures (+/-1 standard deviation).

Each year, typical winter conditions are present in January and February. A high degree of homogeneity within the water column is the normal winter signature for all physical parameters, although storm water runoff may intermittently influence density profiles by causing a freshwater lens within nearshore surface waters. The chance that the wastewater plume may surface is highest during these winter months when there is little, if any, stratification of the water column. These conditions often extend into March, when a decrease in the frequency of winter storms brings about the transition of seasons.

In late March or April, the increasing elevation of the sun and lengthening days begin to warm the surface waters and re-establish the seasonal thermocline and pycnocline to coastal and offshore waters. Once stratification is established by late spring, minimal mixing conditions tend to remain throughout the summer and early fall months. In October or November, cooler temperatures, reduced solar input, and increased stormy weather cause the return of the well-mixed, homogeneous water column characteristic of winter months.

Observed Seasonal Patterns of Physical and Chemical Parameters

The record rainfall of October and December 2004 continued into early 2005, with above normal rain occurring during January and February (**Figure 2.3A**) (NOAA/NWS 2005). Normal conditions returned in March, continued through October, and were followed by drought conditions in November and December. Air temperatures were also extreme in 2005. Unseasonably warm air temperatures approaching the upper confidence limit for the historical average occurred in January–March, May, and November (Figure 2.3B). Despite these circumstances, thermal stratification of the water column followed normal seasonal patterns at the nearshore and offshore sampling areas, with local weather affecting an increase in surface water temperature and nearshore turbidity during the first part of the year.

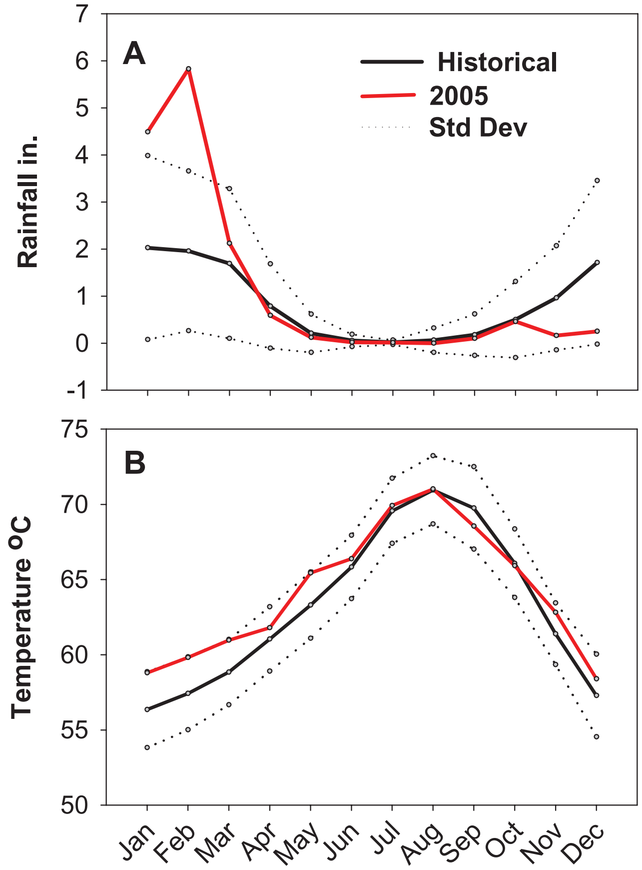

Figure 2.3
Total monthly rainfall (A) and monthly mean air temperature (B) at Lindbergh Field (San Diego, CA) for 2005 compared to monthly average rainfall and air temperature (+/-1 standard deviation) for the historical period 1914–2004.

Temperature is the main factor affecting water density and stratification of southern California ocean waters (Dailey et al. 1993, Largier et al. 2004) and provides the best indication of the surfacing potential of the wastewater plume. This is particularly true of the South Bay region where waters are shallow and salinity is relatively constant. During 2005, average surface water temperatures in January and March were unseasonably warm (15.3 and 16.0 °C, respectively), likely the result of the warmer than normal air temperatures (**Table 2.1**). Coincident with a subsequent decline in air temperature, surface water temperatures fell to 13.7 °C in

Table 2.1

Differences between the surface (≤2 m) and bottom (≥27 m) waters for mean values of temperature (°C), salinity (ppt), density (δ/θ),dissolved oxygen (mg/L), pH, chlorophyll *a* (µg/L), and transmissivity (%) at all SBOO monthly water quality stations during 2005. The greatest differences between surface and bottom values are highlighted and in bold bold type.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature	*Surface*	15.3	ns	16.0	13.7	15.2	19.2	19.6	16.8	17.1	17.7	16.1	14.2
	Bottom	15.2	ns	12.7	10.6	10.3	10.9	11.2	10.7	11.0	12.1	13.1	12.4
	Difference	0.04	ns	3.3	3.1	5.0	**8.3**	**8.4**	6.1	6.2	5.6	2.9	1.8
Density	*Surface*	24.23	ns	24.17	25.01	24.76	23.86	23.73	24.33	24.23	24.11	24.46	24.87
	Bottom	24.56	ns	25.16	25.87	25.90	25.77	25.57	25.66	25.70	25.40	25.15	25.31
	Difference	-0.33	ns	-0.99	-0.86	-1.13	**-1.91**	**-1.84**	-1.33	-1.47	-1.30	-0.69	-0.43
Salinity	*Surface*	32.82	ns	32.95	33.39	33.51	33.55	33.51	33.42	33.37	33.40	33.34	33.37
	Bottom	33.24	ns	33.33	33.74	33.70	33.68	33.49	33.51	33.61	33.50	33.43	33.45
	Difference	**-0.42**	ns	**-0.37**	**-0.35**	-0.19	-0.13	0.02	-0.08	-0.24	-0.10	-0.09	-0.08
DO	*Surface*	7.9	ns	8.1	9.2	7.1	8.5	9.5	9.4	9.4	8.6	8.6	8.0
	Bottom	7.7	ns	6.4	4.1	4.4	4.0	5.8	5.7	4.4	5.2	6.1	5.6
	Difference	0.1	ns	1.8	**5.1**	2.7	**4.6**	3.7	3.7	**5.0**	3.4	2.5	2.4
pH	*Surface*	8.1	ns	8.1	8.2	8.1	8.4	8.4	8.2	8.3	8.1	8.2	8.2
	Bottom	8.1	ns	7.9	7.8	7.9	7.8	7.9	7.9	7.8	7.8	8.0	8.0
	Difference	-0.0	ns	0.2	0.4	0.3	**0.6**	**0.5**	0.4	0.4	0.3	0.2	0.2
XMS	*Surface*	70	ns	71	62	76	72	71	78	72	79	85	84
	Bottom	88	ns	85	86	90	87	89	90	90	89	88	89
	Difference	**-18**	ns	-14	**-25**	-14	-15	**-18**	-13	**-17**	-10	-3	-5
Chl *a*	*Surface*	1.9	ns	2.0	16.8	2.3	10.0	18.3	6.5	12.0	4.3	2.9	3.7
	Bottom	1.7	ns	1.5	2.1	1.2	1.4	2.9	1.7	1.4	2.2	3.2	3.0
	Difference	0.2	ns	0.5	**14.7**	1.1	8.5	**15.4**	4.9	**10.6**	2.1	-0.3	0.7

April. This was followed by seasonal warming of the surface waters that began in May, progressed rapidly, and peaked in July with mean surface temperatures reaching 19.6 °C. A relatively rapid decline of about 3 °C occurred in August, followed by a slight increase during September and October. Thereafter, surface temperatures declined rapidly from 17.7 °C in October to 14.2 °C in December.

Bottom temperatures were also relatively high in January 2005, but fell back to normal in succeeding months (Table 2.1). Bottom water temperatures measured in January averaged 15.2 °C, over 1 °C higher than most other years (**Table 2.2**). They fell to about 12 °C by March, and ranged from 10.2 to 13.1 °C for the remainder of the year.

Although surface and bottom temperatures differed somewhat from previous years, thermal stratification of the water column followed normal seasonal patterns (**Figures 2.4, 2.5**, Table 2.2). Stratification of the water column was minimal or absent during January with the difference between average surface and bottom temperatures being only 0.04 °C. However, stratification started to develop in March and April with differences of >3 °C between surface and bottom temperatures. Thermoclines of ~1 °C over less than 1 meter of depth were present between 4 and 6 m during this period. Thermal stratification was strongest in June and July.

Table 2.2

Differences between the surface (≤2 m) and bottom (≥27 m) waters for mean values of temperature (°C) at all SBOO monthly water quality stations during 2000–2005. The highest annual temperatures for surface and bottom temperatures are in bold type. ns=not sampled (see text).

		2000		2001		2002		2003		2004		2005	
		Mean	Δ	Mean	Δ	Mean	Δ	Mean	Δ	Mean	Δ	Mean	Δ
Jan	*surface*	14.1		14.6		14.2		14.7		13.8		15.3	
	bottom	12.8	1.3	14.1	0.5	13.2	1.0	13.7	1.0	12.8	1.0	15.2	0.1
Feb	*surface*	13.2		14.2		12.8		15.2		13.8		ns	
	bottom	11.9	1.3	12.6	1.6	11.6	1.2	13.9	1.3	11.7	2.1	ns	
Mar	*surface*	13.9		13.9		12.4		15.5		14.2		16.0	
	bottom	11.9	2.0	13.4	0.5	10.7	1.7	11.6	3.9	11.7	2.5	12.7	3.3
Apr	*surface*	15.3		13.9		14.0		15.0		16.7		13.7	
	bottom	10.3	5.0	11.2	2.7	11.3	2.7	10.9	4.1	11.5	5.2	10.6	3.1
May	*surface*	18.0		16.5		15.8		14.8		16.7		15.2	
	bottom	**10.2**	7.8	11.4	5.1	**10.5**	5.3	**10.4**	4.4	11.1	5.6	**10.2**	5.0
Jun	*surface*	16.6		17.8		18.2		17.2		18.9		19.2	
	bottom	**10.3**	6.3	**10.6**	7.2	11.5	6.7	**10.7**	6.5	**10.3**	8.6	**10.9**	8.3
Jul	*surface*	19.1		18.0		18.2		**19.3**		18.4		**19.6**	
	bottom	12.1	7.0	11.8	6.2	**10.6**	7.6	11.4	7.9	**10.7**	7.7	11.2	8.4
Aug	*surface*	**20.3**		18.1		17.3		17.2		20.1		16.8	
	bottom	12.7	7.6	11.1	7.0	**10.8**	6.5	**10.8**	6.4	11.6	8.5	**10.7**	6.1
Sep	*surface*	18.4		17.1		**19.7**		18.2		**22.2**		17.1	
	bottom	11.8	6.6	11.4	5.7	11.7	8.0	11.6	6.6	12.7	9.5	11.0	6.1
Oct	*surface*	20.0		**19.1**		17.0		17.5		17.4		17.7	
	bottom	13.4	6.6	12.6	6.5	11.9	5.1	12.5	5.0	12.0	5.4	12.1	5.6
Nov	*surface*	17.0		15.9		15.7		16.9		18.2		16.1	
	bottom	12.5	4.5	13.4	2.5	12.4	3.3	13.5	3.4	14.3	3.9	13.1	3.0
Dec	*surface*	14.6		14.2		15.9		15.6		15.7		14.2	
	bottom	12.4	2.2	13.8	0.4	14.6	1.3	**13.8**	1.8	14.4	1.3	12.4	1.8

Temperature differences between surface and bottom waters were >8 °C with thermoclines of ~3 °C over 1 meter depth. A weaker shallow thermocline (~1 °C) persisted into October, but became undetectable in CTD profile data by November.

Deviations from this generally thermal-driven pattern occurred in April and August when surface and mid-level water temperatures dipped (Figures 2.4, 2.5 and Table 2.1). These cooling events are similar to those of previous years and may be the result of localized upwelling associated with the inshore movement of water from the California Current (see City of San Diego 2004, 2005a). A recent study of upwelling within the South Bay sampling region suggests that these events may not be primarily wind-driven, but rather due to topographic features that create a divergence of the prevailing southerly flow as it passes the Point Loma headland (Roughan et al. 2005).

Surface water salinity in 2005 displayed some seasonal patterns related to increasing air temperatures, rain runoff, and the April upwelling (see Figures 2.4, 2.5). Surface salinity at the monthly water quality stations ranged from 32.82 to 33.55 ppt (Table 2.1). Substantial freshwater inputs from winter storms during January–March resulted in average near-surface salinity values below 33 ppt. These conditions allowed for the development of salinity haloclines near the surface (1–5 m) during January–March. In contrast, warm air temperatures and the influx of cold, upwelled waters held surface, mid, and bottom water salinities to above 33.3 ppt for the remainder of the year.

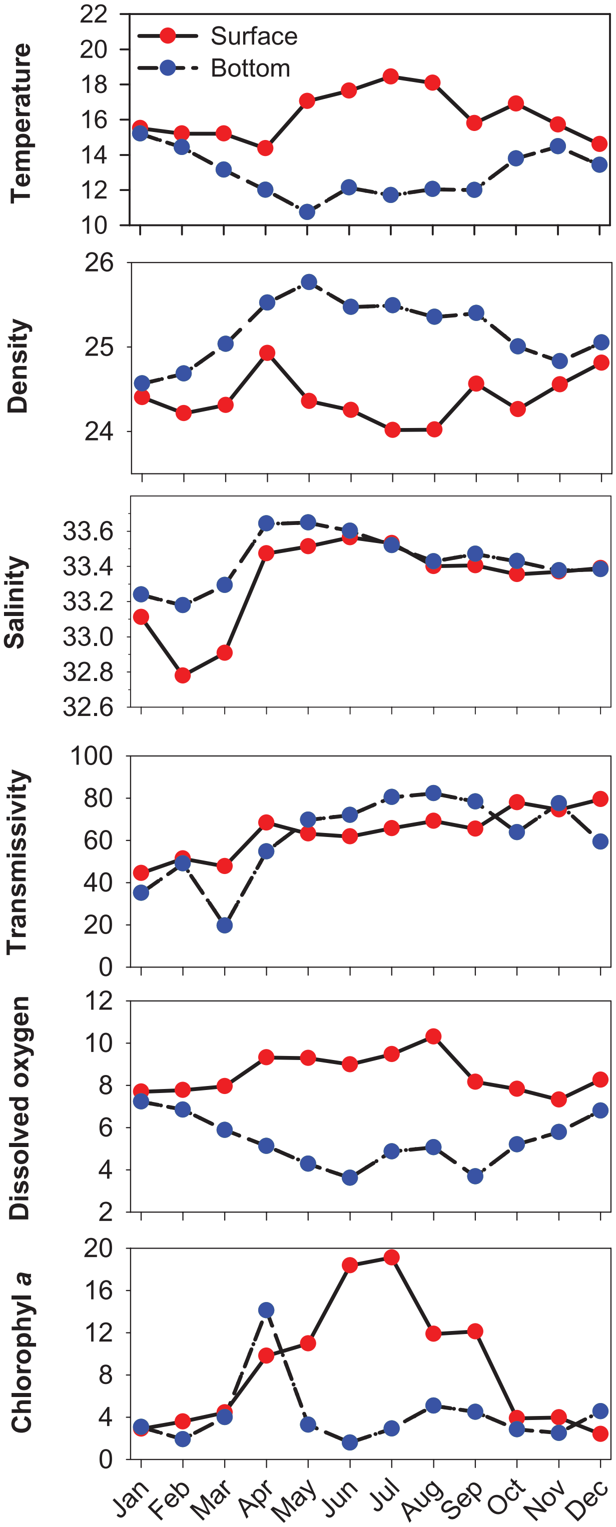

Figure 2.4

Monthly average temperature (°C), density (δ/θ), salinity (ppt), transmissivity (%), dissolved oxygen (mg/L), and chlorophyll a (µg/L) values for surface (<2m) and bottom (≥18m) waters at the three kelp water quality stations during 2005.

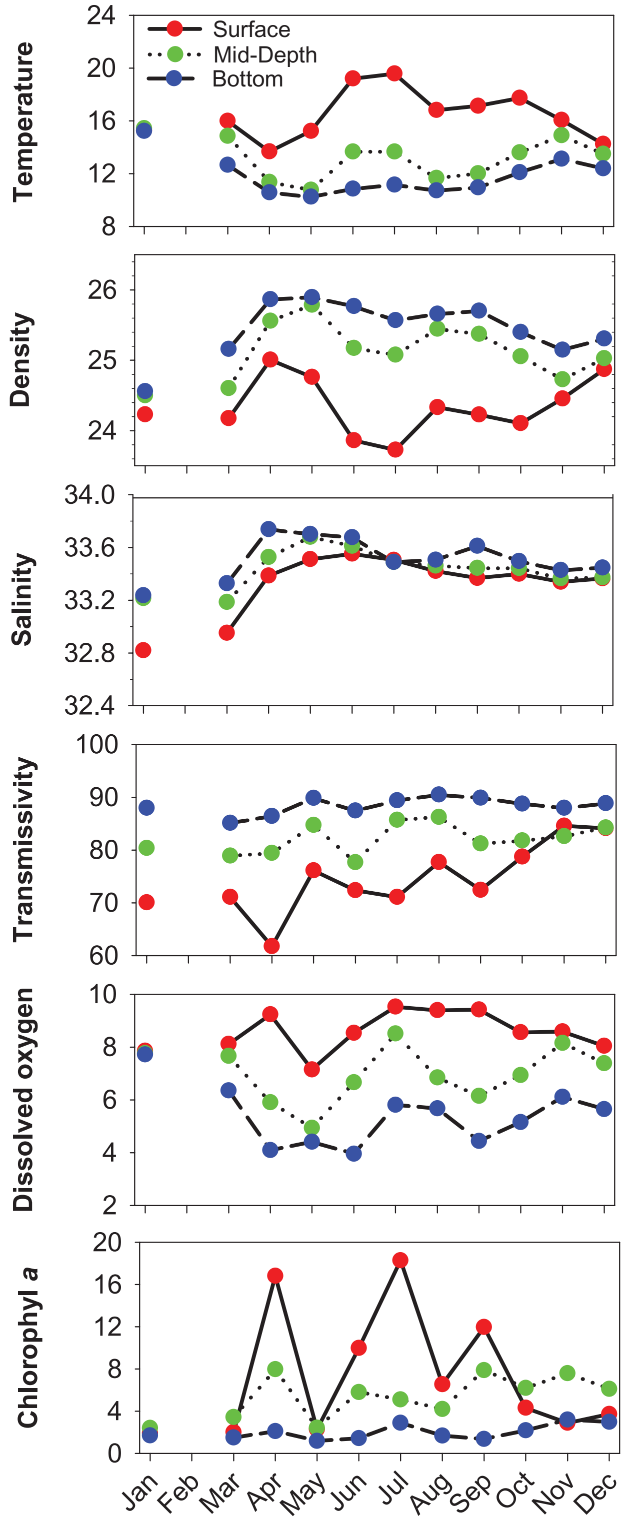

Figure 2.5

Monthly average temperature (°C), density (δ/θ), salinity (ppt), transmissivity (%), dissolved oxygen (mg/L), and chlorophyll a (µg/L) values for surface (<2m), mid-depth (10–20 m) and bottom (>27m) waters at the monthly water quality stations during 2005.

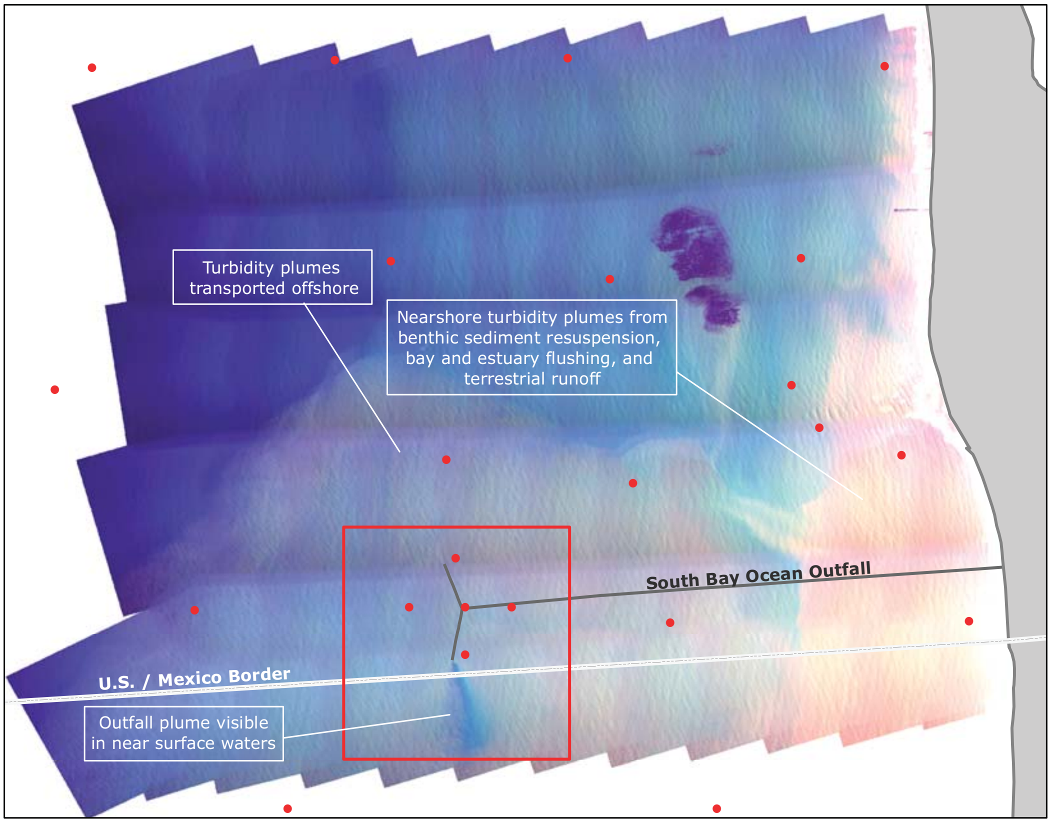

Figure 2.6
DMSC image composite acquired on January 12, 2005 showing the SBOO outfall and coastal region after heavy rains. The Tijuana River plume reached several kilometers west of the outfall wye. The outfall plume effluent displaced the shallow heavily turbid runoff layer and appears clearer.

Although density is a product of temperature, salinity and pressure, temperature is the principal component that drives density in the South Bay area because of the relatively shallow depths and the relative uniform salinity profiles. Therefore, changes in density typically mirror changes in temperature. This inverse relationship was true for the 2005 data collected by CTD at the South Bay kelp and offshore monthly water quality stations (see Figures 2.4, 2.5). Offshore surface water density was lowest in June and July, when surface waters were warmest. The difference between surface and bottom water densities was greatest from May through October, with the resulting pycnocline contributing to the stratification of the upper column at the time.

Remote sensing generally confirmed the above observations of water column stratification. For example, DMSC aerial imagery detected the outfall plume's near-surface signature in January and the latter part of February when the water column was well mixed (Ocean Imaging 2005a: **Figure 2.6**). Subsequent aerial imagery indicated that the outfall plume remained in the lower part of the water column from March through December (Ocean Imaging 2005a, b, 2006). Despite water column profile data from kelp and monthly water quality surveys suggesting an unstratified water column in November and December, the wastewater plume was not detected in surface waters by remote sensing until mid-December (Ocean Imaging 2006).

Observed Patterns in Turbidity and Plankton

The record rainfall in late 2004 through early 2005 caused large volumes of turbid runoff to exit from San Diego Bay, the San Diego and Tijuana Rivers, and Los Buenos Creek. The affects of this storm-driven surface turbidity were apparent in nearshore and offshore transmissivity measurements. For example, mean surface and bottom transmissivity measurements at the kelp bed stations were below 70% through May 2005 (Figure 2.4). Moreover, runoff containing agricultural and effluent materials from the Tijuana River during the heavy rains of January through March combined with cooler, nutrient-rich water upwelled near the Point Loma headland and created favorable conditions for plankton blooms.. The density of these blooms reduced offshore surface water clarity to near or below 75% for much of the year in the (Figure 2.5). Together, the storm and plankton-driven turbidity reduced surface water transmissivity values for 2005 by 7% compared to 2004 values (City of San Diego 2005a).

Patterns of turbidity caused by storm runoff, tidal flushing of the bay and rivers, and plankton acted as markers of water movement visible in the satellite imagery (see **Figure 2.7**). Although surface currents (0–15 m) typically flow southward in the Southern California Bight (Dailey et al 1993), analysis of MODIS imagery captured in 2005 shows intermittent northward flows in ~13% of the images. These northward flows were slightly more frequent from January through March and October through December (16%) than from April through September (11%). The highest frequency of northward flows occurred during the heavy rains of January–February (28%) and in August (40%), whereas the lowest frequency (0%) occurred in March and June. For example, record rainfall in February combined with relative strong northward current episodes to create turbidity plumes from the Tijuana River that extended to the northwest over the SBOO (Figure 2.7A). Later in the year, strong northward currents carried turbidity flows from San Diego Bay northwestward over the Point Loma outfall pipe (Figure 2.7D). In contrast, the typical southward flow was evident in patterns in nearshore turbidity and the movement of dense plankton blooms in April and June (Figures 2.7B, C).

Red tides present in the region from April through October were due to a bloom of the dinoflagellate *Lingulodinium polyedra*. This species has dominated the Southern California Bight since 1995. Gregorio and Pieper (2000) have found that the species persists at the Los Angeles River mouth from winter through summer and that river runoff during the rainy season provides significant amounts of nutrients that allow for rapid population increases. Runoff containing agricultural and effluent materials from the Tijuana River during the heavy rains of January through March most likely contributed to the widespread red tides observed in South Bay. In addition, cooler, nutrient-rich water upwelled near the Point Loma headland can drift south towards the Tijuana River mouth enriching conditions for plankton bloom development (Roughan et al. 2005).

Aerial imagery and chlorophyll *a* data indicated that the plankton bloom were strongest near Imperial Beach and the Tijuana River mouth (**Figure 2.8**). CTD profile data indicated that peak surface chlorophyll *a* concentrations occurred in April, June, July, and September. Corresponding declines in mean transmissivity values as well as increases in dissolved oxygen and pH indicate that this bloom persisted throughout the summer and fall and was strongest in April and July. The reduced oxygen values at mid and bottom depths during September were likely due to the biological and detrital oxidation associated with a fading plankton bloom (Pickard and Emery 1990).

SUMMARY AND CONCLUSIONS

Oceanographic conditions during 2005 were generally within expected seasonal variability. Rainfall was well above average during January and February, near average from March through October, and below average during November and December. The influx of freshwater during January through March contributed to shallow haloclines as well as large plumes of turbid water along shore that occasionally passed over the outfall. Surface temperatures differed from previous years as unseasonably high air temperatures in January–March contributed to warmer than normal winter surface waters. The maximum surface temperatures

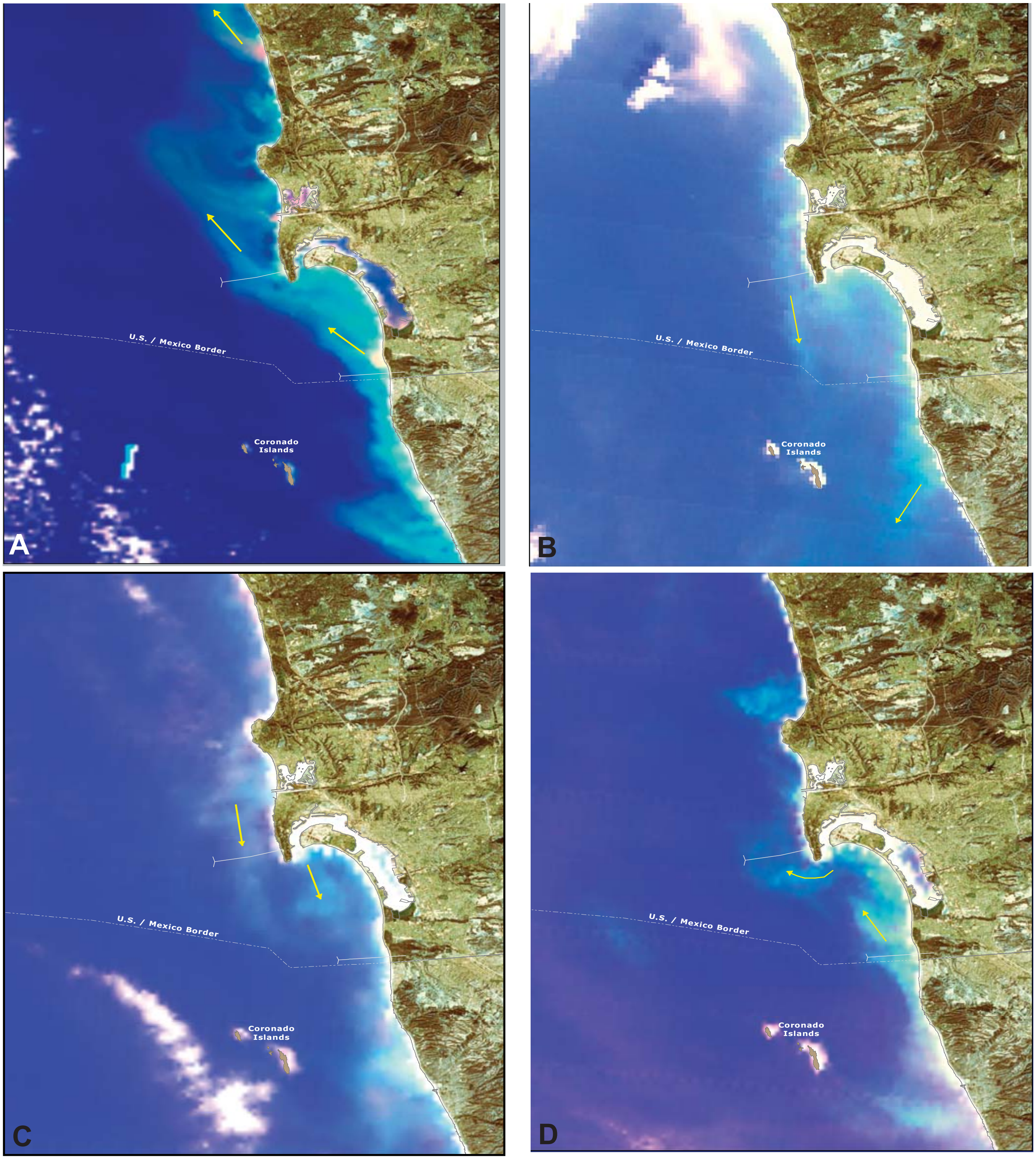

Figure 2.7

MODIS satellite image showing the San Diego region, captured during 2005 on (A) February 24, (B) April 15, (C) June 22, (D) October 10, and (E) December 9. White pixels offshore represent areas obscured by cloud cover. White pixels along the shoreline are due to "washout" or band saturation and to the histogram stretches used to enhance turbidity features in surface waters.

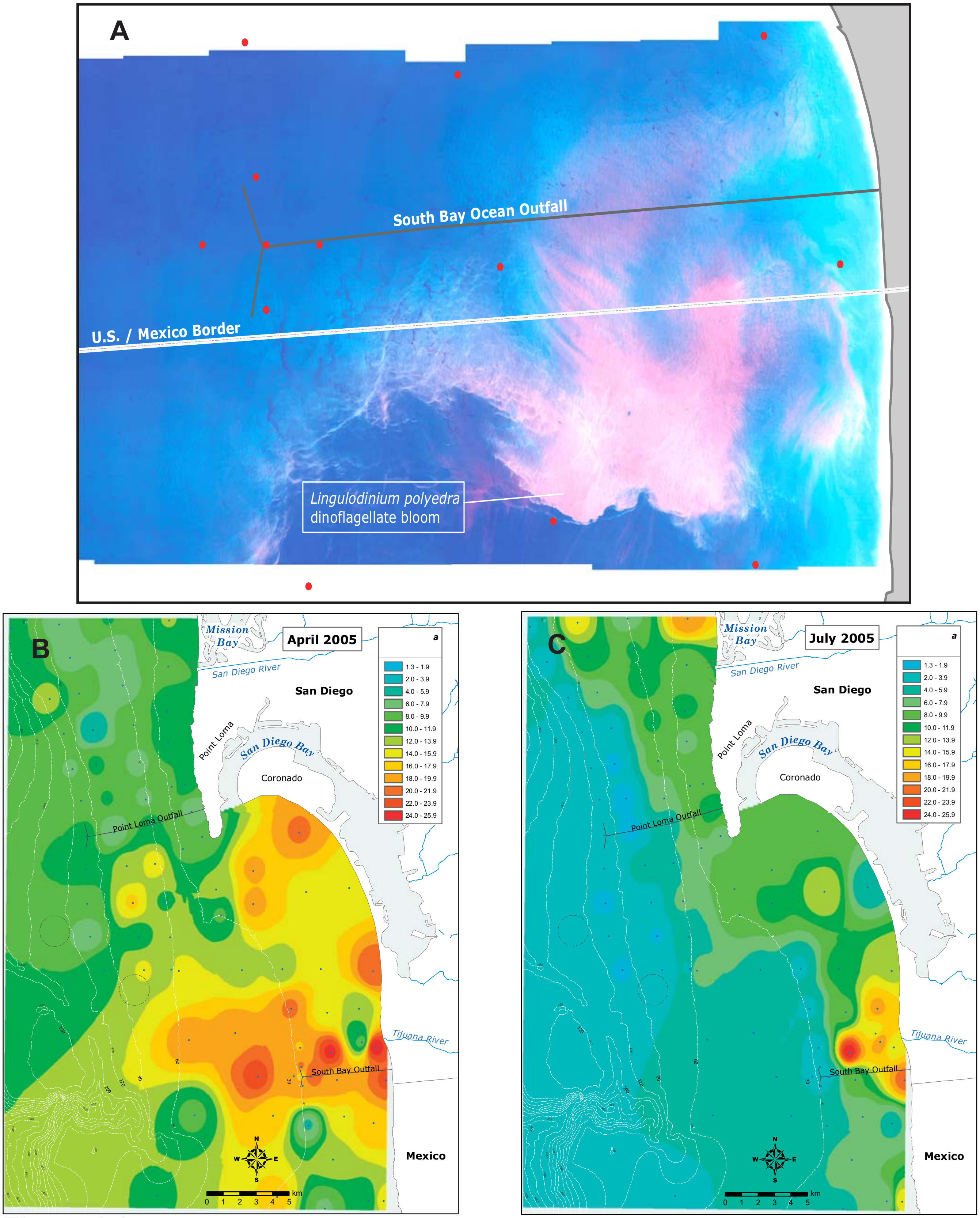

Figure 2.8

DMSC image composite acquired on August 26, 2005 showing (A) the SBOO outfall and coastal region during a red tide, and ArcView maps for (B) April and (C) July 2005 indicating surface chlorophyll *a* distribution ($\leq$15m) along the San Diego coastline.

occurred in early summer (June and July) and declined in late summer (August and September) when mean air temperatures fell below a 90-year average. Bottom temperatures were also higher than normal in January 2005, but fell back to normal in succeeding months. Despite the minor deviations from expected surface and bottom temperatures, thermal stratification of the water column followed typical patterns. Water column stratification began to develop in March and persisted through October.

Record rains produced significant turbidity flows from San Diego Bay, the San Diego River, the Tijuana River, and Los Buenos Creek during the first few months of the year. Upwelling in April and August appeared to contribute to a massive red tide that was present from April through October, particularly along the shallower depth contours. Patterns in surface water turbidity resulting from these events revealed a predominantly northward current regime in the South Bay region from January through March, and a southerly flow thereafter.

Remote sensing observations generally confirmed the above pattern of water column stratification. The outfall plume's near-surface signature was detected by DMSC aerial imagery in January and the latter part of February when the water column was well mixed, but remained in the lower part of the water column from March through December (Ocean Imaging 2005a, b, 2006). Finally, aerial imagery indicated that runoff from the Tijuana River and occasionally San Diego Bay appeared to be significant factors in increasing turbidity and contamination to surface waters of the South Bay region, while the wastewater plume from the outfall tended to have a less significant effect. In general, data from water column measurements for the region, together with remote sensing data, revealed little evidence of impact from the SBOO.

LITERATURE CITED

Bowden, K.F., 1975. Oceanic and Estuarine Mixing Processes. In: Ed., J.P. Riley and G. Skirrow, eds. Chemical Oceanography, 2nd Ed. Academic Press, San Francisco.

City of San Diego. (2004). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (International Wastewater Treatment Plant), 2003. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2005a). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (International Wastewater Treatment Plant), 2004. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2005b). Letter to the Regional Water Quality Control Board, Region 9, dated February 8, 2005. Located at: San Diego Regional Water Quality Control Board offices, San Diego, CA.

City of San Diego. (in prep.). EMTS Division Laboratory Quality Assurance Project Plan. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Dailey, M.D., Reish, D.J. and Anderson, J.W. (eds.) (1993). Ecology of the Southern California Bight: A Synthesis and Interpretation. University of California Press, Berkeley, CA. 926 pp.

Gregorio, E. and R.E. Pieper. (2000). Investigations of red tides along the Southern California coast. Southern California Academy of Sciences Bulletin, Vol. 99 (3): 147–160.

Largier, J., L. Rasmussen, M. Carter, and C. Scearce. (2004). Consent Decree – Phase One Study Final Report. Evaluation of the South Bay International Wastewater Treatment Plant Receiving Water Quality Monitoring Program to Determine Its Ability to Identify Source(s) of Recorded Bacterial Exceedances. Scripps

Institution of Oceanography, University of California, San Diego, CA. 241 pp.

NOAA/NWS. (2005). The National Oceanic and Atmospheric Association and the National Weather Service Archive of Local Climate Data for San Diego, CA. http://www.wrh.noaa.gov/sandiego/climate/lcdsan-archive.htm

North, W.J. (1991). The Kelp Beds of San Diego and Orange Counties. 270 pp.

North, W.J., D.E. James, and L.G. Jones. (1993). History of kelp beds (*Macrocystis*) in Orange and San Diego Counties, California. Hydrobiologia, 260/261: 277–283

Ocean Imaging. (2005a). Satellite and Aerial Coastal Water Quality Monitoring in the San Diego/Tijuana Region: Monthly Report for January, February & March 2005. Solana Beach, CA.

Ocean Imaging. (2005b). Satellite and Aerial Coastal Water Quality Monitoring in the San Diego/Tijuana Region: Monthly Report for April through September 2005. Solana Beach, CA.

Ocean Imaging. (2006). Satellite and Aerial Coastal Water Quality Monitoring in the San Diego/Tijuana Region: Monthly Report for October through December 2005. Solana Beach, CA.